Laboratory and Mine Scale Evaluation of Smoke Detectors

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Several experimental programs were conducted under the U.S. Bureau of Mines to investigate the level of mine fire detection and alarm capability currently possible using state-of-the-art technology. These programs involved comparison of the response and alarm time of optical and ionization type smoke detectors to smoldering and flaming coal combustion in a smoke chamber (1). One optical type detector operated in a diffusion mode, and a second in a pump mode. Two of the ionization type detectors operated in a pump mode, and two in a diffusion mode. CO concentration and smoke optical density were continuously measured. The coal combustion experiments conducted in the smoke chamber demonstrated that a CO concentration 5 ppm above background corresponded to an optical density of 0.022 m^{-1}. For the four smoke detectors for which a measurable continuous analog signal was available, a smoke detector alarm was defined as the average background signal plus ten times the peak-to-peak noise. This alarm criterion resulted in the association of the alarm for three of the four detectors with a smoke optical density of 0.011 m^{-1}, and 0.033 m^{-1} for the fourth smoke detector. An ionization type smoke detector which operated in a diffusion mode and had only an on-off output signal alarmed at an optical density of 0.12 m^{-1} for smoldering coal combustion, and 0.077 m^{-1} for flaming coal combustion. A prototype ionization type pump mode smoke detector, a submicron particle detector, was used to measure a number mean smoke particle diameter of 0.45 μm for smoldering coal combustion and 0.38 μm for flaming coal combustion. At an optical density of 0.022 m^{-1}, a comparison was made of the detectors' signal for the smoldering and flaming coal combustion experiments. The optical-type smoke detectors responded with greater intensity to smoldering than to flaming coal combustion; whereas the ionization smoke detectors responded with greater intensity to flaming than to smoldering coal combustion. As part of the smoke detector evaluation experiments, an odor monitor's response to the smoke was recorded. For the smoldering coal combustion experiments, the odor monitor alarm time was defined as the monitor's equivalent response to 1 ppm of H_2S, associated with combustion products from sulfur containing Pittsburgh seam coal. For the smoldering coal combustion experiments the odor monitor alarm time was earlier than the CO alarm time, whereas the odor monitor and CO alarm times were comparable for the flaming coal combustion experiments. A comparison of the odor monitor's alarm time with one of the ionization smoke detector's alarm time showed equivalency for smoldering coal combustion, whereas for flaming coal combustion the smoke detector alarmed prior to the odor monitor.

The smoke detectors used in the smoke chamber studies were incorporated into large scale diesel fuel fire experiments conducted under normal ventilation conditions in the Safety Research Coal Mine (SRCM) located at the Pittsburgh Research Center (2). In those studies a relative comparison was made of the smoke detector alarm time to that of a diffusion mode CO detector. Two diffusion mode smoke detectors, one ionization and one optical type, alarmed earlier than a diffusion mode CO detector. Based upon the measurement of the optical light transmission at the location of a pump mode ionization type smoke detector, it was determined that the smoke detector alarmed at an average optical density of 0.021 m^{-1} for the twelve experiments conducted.

Two ultrasonic ranging systems were used to demonstrate their response to smoke and heat in eighteen underground mine-fire experiments (3). In one of the experiments smoke candles instead of a diesel fuel fire were used to demonstrate that the ranging system responded to smoke in the absence of heat. In an experiment conducted in the intermediate scale fire tunnel with a coal fire, and a ranging system alarm defined as the average background signal plus ten standard deviations, the smoke optical density at the alarm was 0.025 m^{-1}.

REFERENCES

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